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CONFIGURATIONS OF HIGH FREQUENCY ELECTROMAGNETIC FIELDS IN ASSOCIATION WITH A MAGNETOSTATIC FIELD WITH THE VIEW OF CONFINING A PLASMA

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CONFIGURATIONS OF HIGH FREQUENCY ELECTROMAGNETIC FIELDS IN ASSOCIATION WITH A MAGNETOSTATIC FIELD WITH THE VIEW OF CONFINING A PLASMA

(Configurations des champs électromagnetiques de haute fréquence et magnétostatique associés en vue du confinement d'un plasma)

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by Jacques Pottier

ABSTRACT

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The frequency of an electromagnetic field confining a plasma may be lowered if a magnetostatic field is utilized jointly.

The conditions which such combinations must satisfy are examined succinctly and several solutions are proposed.

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INTRODUCTION.- An electromagnetic field of frequency f exerts upon a plasma forces often containing an important component of frequency 2f under whose effect the boundary of the plasma oscillates in case of a confinement [1, 2, 3]. In order to maintain this amplitude low in front of the dimensions of the confining device, one is then led to utilize rather high frequencies and this raises a certain number of difficulties [2].

One may think of limiting plasma flows perpendicularly to its surface with the aid of an auxiliary static magnetic field so as to be able to make use of a lower frequency.

RESPECTIVE ARRANGEMENTS OF THE FIELDS AND PLASMA. — The lines of force of the static magnetic field B_0 must obviously be nearly parallel to the surface of the plasma. If the field B is enjoined to be a true static field whose tubes of force bound the plasma, this must be produced with the aid of a self-sealing solenoid.

Difficulties arise when the electric field E is perpendicular to the surface of the plasma, and also when E is perpendicular to B_0 (inversion forces exerted at passage from plasma frequency to gyro-frequency [3, 4]). The case when B_0 and E are sensibly longitudinal relative to the plasma tube, and thus B, the magnetic component of the high-frequency field, sensibly transverse, offers a particular interest.

The confinement mechanism is as follows :

Longitudinal currents J_Z are generated in the plasma according to the direction common to E and B_0.

The action of the azimuthal component B_θ of the transverse magnetic field upon these currents provides the mean pressure gradient in time $\nabla p = \langle J_Z B_0 \rangle$.

To avoid leaks through the HF field's magnetic poles, one is led to utilize rotating configurations of the HF fields.

ROTATING CONFIGURATIONS OF HF MULTIPOLAR MAGNETIC FIELDS.-

The utilization of simple rotating fields meets with a difficulty — the carrying away of the plasma by the field, effect due to the true component of the conductivity as for the rotor of an induction motor [3, 5, 6]. If the angular velocity of the plasma ω_r may approach the synchronous velocity of the field ω, one may consider that the plasma is only subjected to a field rotating at the low sliding velocity $\omega_g = \omega - \omega_r$. The currents J_Z, induced in the plasma, decrease as ∇p, but azimuthal currents J_φ may appear, leading to a different confinement mechanism, utilizing the forces in $J_\varphi B_0$ already known [6] and observed in the course of an experiment described in a preceding paper.

In case of a totally ionized plasma in a permanent regime, the electronic and ionic currents J_φ annul themselves, and the whole process is doomed to failure difficult to avoid.

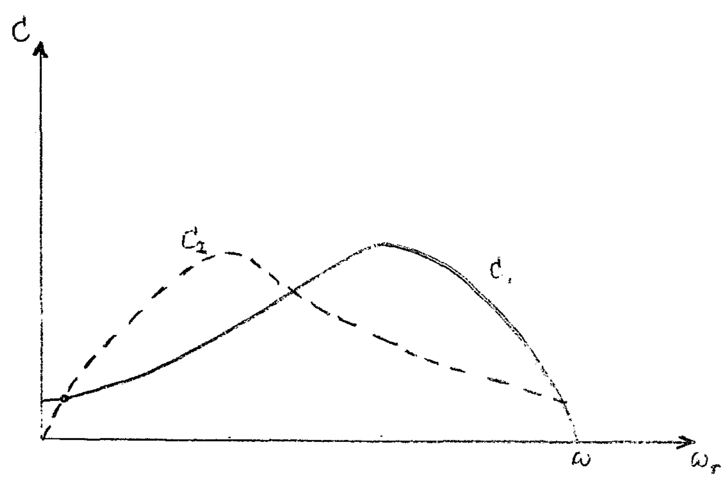
To utilize then the mechanism in $\nabla p = \langle J_Z B_0 \rangle$, one may utilize two configurations of magnetic fields rotating at different velocities. The plasma cannot then be synchronous for the two motions at the same time. A simple case is that where ont of the configurations is purely static, transverse to B_0, and the other rotates. The rotation speed of the plasma is determined by the characteristic of the couple as a function of the sliding velocity of the plasma relative to the field.

If the plasma is strongly reactive, one may show than the is maximum for a low sliding velocity.

We represented in Fig. 1 the torque C_1 exerted upon the plasma by the field rotating at the speed ω and the braking torque C_2 exerted by the fixed field.

We may see that the plasma velocity for which the torques are equilibrated when one starts from a zero speed is low, and that this point corresponds to a steady equilibrium. In case of little reactive plasma, the equilibrium velocity would get nearer the mean velocity.

In fact, fields rotating at different speeds are realized by linear combinations of stationary fields of various frequencies. Another solution (simultaneously conceived by M. Taillet) allowing to keep the plasma practically motionless relative to a rotating field consists in reversing the direction of field rotation at a sufficiently rapid timing.



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(C. E. N. Saclay)

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